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# AN ANALYSIS OF ORGANIZATIONAL STRUCTURES FOR INTEGRATING R&D WITH MANUFACTURING AND MARKETING

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# AN ANALYSIS OF ORGANIZATIONAL STRUCTURES FOR INTEGRATING R&D WITH MANUFACTURING AND MARKETING


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## INTRODUCTION

Managerial concern for increasing the cost-effectiveness of research and development activity often centers around techniques to improve the individual performance of scientists and engineers and the equipment or materials they use. However, such a focus tends to divert management attention from problems concerning the efficient interaction (i.e., cooperation and teamwork) of scientists and engineers among themselves, as well as the overall integration of research and development with manufacturing, marketing, and staff support activities.

It is clear that the discoveries, developments, intentions, and innovations resulting from science and engineering are of little or no practical value without proper application to the problems of society. The efficient application of these outputs of research and development is dependent upon how well and how quickly they can be produced and made available to society through marketing distribution.

In addition, marketing research should have a major interactive role with research and development in determining the direction of science and engineering endeavors. Societal needs assessment by marketing research can provide a greater opportunity for more useful and beneficial research and development results, even though, concurrently, it may limit individual scientists and engineers from pursuing projects of personal interest. Top strategic managers should be aware of the coordinative-cooperative problems and resultant friction that this condition may cause between market research specialists and research and development personnel.

Problems of interpersonal behavior affecting the relationship of scientists and engineers also should be of constant concern to management, since scientists, especially basic scientists, and engineers often have distinctively different personalities, perspectives, and goals (1). Without effective managerial coordination of these technical specialists, conflicts between them will slow or stop the smooth flow of scientific discovery to engineering applications.

Moreover, development engineering designs must be capable of being manufactured in an efficient and timely manner. Continual liaison between engineering and manufacturing activities by management can provide concurrence of product and process design, thereby ensuring that engineering developments may be readily transformed into products. Without the staff administrative and technical support provided by other areas of institutional activity such as finance, personnel administration, procurement, legal, and maintenance, research and development and its line-unit organizational partners of manufacturing and marketing cannot be cost-effective.

Organizational structure provides the linking mechanism through which management can integrate and coordinate all of these areas of operational activity (2). The relevant organizational structure can be built upon (i) a base which emphasizes professional specialties, (ii) a functional processes base, or (iii) a specific products-projects base. These three structures are respectively referred to in this analysis as Specialty-Based Structure, Process-Functional Based Structure, and Matrix-Project Based

Structure. Each structural approach has inherent resource utilization and coordinative advantages and disadvantages, particularly from the standpoint of linking research and development with manufacturing, marketing, and staff support. Therefore, it is not uncommon to find larger institutions using some combination of these three basic types of organization structure in order to have the most efficient structural arrangement of their total production process.

The objective of this paper is to compare and contrast these structural approaches to research and development management by reviewing their respective strengths and weaknesses. The concept applications and charts used herein primarily focus on research and development-oriented operations. However, these same organizational concepts also may be utilized on a broader scale to integrate research and development with manufacturing, marketing, and centralized staff support activities.

## SPECIALTY-BASED STRUCTURE

All organizational structures are based to some degree on professional specialties. Essentially, a professional specialty-based structure groups together individuals with similar training, interests, and credentials, regardless of the specific projects or functional work areas with which they may be involved (3). The instrument for orchestrating such groupings is the organizational unit. The more limited or narrow the specialty grouping (e.g., mechanical, electrical, civil, chemical, and material engineers), the more likely the organizational unit will be smaller and located at a lower level of the overall institutional structure.

A larger organizational grouping, however, might be illustrated by an aerospace engineering unit. This type of clustering can be viewed as an organizational bridge between specialty and functional units, since aerospace engineers are often engineers with more specific sub-specialties (as stated above) who have a focused interest on broader aeronautical-space oriented systems. The same might be said for agricultural, petroleum, marine-oceanic, or bioengineering.

From the technician standpoint, a professional specialty grouping might place glass-blowers in the same organizational unit regardless of the purpose or use of their output. Support personnel might be similarly grouped, such as placing all cost accountants or all computer programmers in one specific unit of the structure. A basic problem associated with specialty groupings can be demonstrated by a structure where all secretaries would be located in the same unit. With this type of grouping, there would be little opportunity for managers throughout the structure to really have "private secretaries." Such structural arrangements clearly impose specialty over process. In short, specialty-based structures can limit the direct integration of specialists with other organizational members whose own work might depend heavily on the specialists' expertise or results.

Specialty organizational groupings can also cause myopic perspectives which impede a more institutionalized team-oriented outlook by the work force. Cooperation is hindered when specialities become an end in themselves rather than an avenue through which the institution can efficiently meets its objectives. Institutional objectives become vague or lost in the pursuit of specialty excellence. In addition, little cross-fertilization of ideas may occur in the specialty based structure. This condition results from communications being specialty based and, therefore, often politically motivated to enhance the importance of the specialty rather than the cost-effectiveness of the institutional production process. Any type of organizational isolation can restrict communications and, therefore, impede broad institutional cooperation and teamwork.

All of these problems are exacerbated if the specialty units appear at upper levels of the organizational structure. When highly specialized organizational units are located at higher levels of the structure, the result is often a larger total number of organizational units, and the span of control for top managers can easily become excessive. In contrast, process-oriented functional structures, to be discussed later, tend to group closely-related specialty units and, thereby, reduce span and related coordinative problems for top management (4).

Nevertheless, specialty-based structures have certain distinct advantages associated with them, particularly if the micro specialty units are located at lower levels of the structure. Specialty-based organizational groupings often breed strong mutual support groups within the specialties themselves. Thus, the very problem of these groupings from a broad institutional team perspective may provide, from a narrower viewpoint, an intellectually comfortable environment for the specialists (especially among R&D personnel) to develop more skill and confidence in their particular areas of expertise. Moreover, the specialists are artificially sheltered by organizational boundaries from other individuals or units whose presence or actions might detract from the specialists' ability to excel in their chosen field. For certain individual personalities and specialties, such protection from the larger institution is desirable. This is particularly important in the case of highly complex micro-oriented tasks as might be found in basic science activity.

Since there clearly is some desire in most individuals to work closely with others of similar backgrounds and interests, organizational structures usually have multiple threads of specialty groupings running through them. This natural occurrence can facilitate the practice of management by allowing managers, especially those at lower organizational levels, to supervise more homogeneous work groups. In short, specialty-based structures typically encourage managerial efficiency on a within-unit basis.

Chart A and its subcharts A1, A2, and A3 present a hypothetical specialty-based organizational structure model for an institution with research and development as its primary mission. The model illustrates narrow specialty units, as well as organizational units of intermediate specialization. The latter units are organizational bridges between highly specialized and functional-process structural components. Since the model depicts a research and development-oriented institution, administrative and technical support staff organizational components also are shown.

## PROCESS-FUNCTIONAL BASED STRUCTURE

The process-based organizational structure is readily adaptable to research and development activity. At the root of process-oriented organizational structures are functional areas of work activity. These functional areas include marketing research, research and development, manufacturing-operations, marketing distribution, and installation-customer service. Such functional activities can be neatly arranged in a structural pattern that aligns with, and gives continuity to, the flow of the production process (5).

Generally, professional specialties are grouped in specialized organizational subunits of the functional divisions. However, these specialty units usually appear at relatively low levels of the structure and are subordinated in organizational importance to the broad process-focused functional areas. Due to its deemphasis on professional specialties (particularly technical specialties) and its emphasis upon divisionalization-departmentalization aligning with the flow of the production process, the process-functional structure provides a strong base for building a team-oriented production effort in technology-based institutions.

In this organizational arrangement, each functional activity needs the output of the other functional areas in order to operate. Thus, for example, research and development depends upon market research, manufacturing-operations depends upon research and development, marketing distribution depends upon manufacturing-operations, and installation-customer service depends upon distribution. All of these areas, in turn, depend upon the staff support functions. Chart B depicts an organizational structure model for a broadly-based manufacturing firm with the fundamental line activities of research and development, manufacturing, and marketing (accompanied by staff support units on Chart B1) arranged in a functional production process flow pattern.

Similar interdependent relationships exist within each functional area. Accordingly, as shown in Chart C, within the R&D area, applied research (fitting theory to design needs and problems) is dependent upon the output of basic research and science, design and development are dependent upon applied research, and test and applications are dependent upon design and development. These particular functionally-interdependent units usually appear at the middle levels of the overall structure. Illustrating how this functional interdependency process flow can appear at even lower levels, a design and development unit might have basic "blue-sky" design, feasibility-value design modification, and aesthetic-industrial design as its organizational subunits.

In the process-oriented structure, each major and subfunctional unit of the organization must have the support and output of the other units not only to be efficient, but to carry out their part of the production effort. Such an interdependent relationship promotes cost-effective institutional teamwork, while concurrently reducing the time and resource waste of destructive political infighting between professional specialties. In addition, the parallelism of the functional pattern of organization to the actual flow of the production process breeds morale-building continuity of perspective for all members of the institutional work force. Employees can see their relative organizational roles more clearly and, accordingly, better appreciate the importance of each unit's respective contribution to the total production effort.

However, as specialty emphasis disappears in the process-functional structural arrangement, specialty pride and identification loss may reduce the morale of technical personnel. This condition can adversely affect the performance of scientists and engineers who must stay narrowly focused in order to successfully carry out complex research and design tasks.

A second potential drawback of process-functional based structures is their tendency to discourage the development of good general managers with extensive cross-functional experience. In these structures, promotion and advancement usually take place within the employee's functional area, and exposure to other functional areas is typically minimal. Consequently, managers promoted up through the ranks of a functionally-structured organization are often not prepared to objectively deal with the multi-functional responsibilities of a general manager. An individual's technical prowess may facilitate his or her promotion within a research and development department, but such prowess may be a poor predictor of general management competency.

Another weakness commonly associated with process-functional based structures is their tendency to exacerbate the negative impact on the entire organization of deficiencies in any single process or functional area. These structures operate as systems where each unit is tightly and inextricably tied to others. In such a structural arrangement, the strength of the structure will only be as strong as the strength of its weakest link. In a process-functional based structure, a design flaw originating in the research and development department, for example, can easily delay the assembly and distribution of the firm's product, thereby detracting from overall organizational effectiveness.

## MATRIX-PROJECT BASED STRUCTURE

A hybrid structural framework, generally referred to as project or matrix organization, can be particularly effective for organizing complex high-tech institutions in which multiple and diverse projects exist (see Chart D) (6). The primary justification for using this organizational pattern involves the need to achieve a high degree of flexibility and coordination in the production process and concurrently avoid the disadvantages of management by discipline or project alone (7). The matrix structure can be particularly effective for the coordination of multi-project, multi-product research and development activity. However, unless there is a substantial need for such coordination and related resource flexibility, the matrix structure is often not chosen as it may generate far more organizational problems than it eliminates (8).

The basic distinguishing feature of matrix organization is a cross-structure chain of managing superimposed upon a functional-process framework, usually denoted on organization charts by solid diagonal lines (9). The cross-structure chain is the key element in achieving the capability to coordinate an array of diversified projects. Each project or product line has its own individual manager who shares jurisdiction in the various functional areas with the managers of the functional units (including the research and development unit). Through this organizational system the project managers are able to monitor and, to an extent, direct all functional-area activity relating to their particular projects so that a highly coordinated effort is sustained for each project. Additionally, the project managers gain a appreciation and understanding of how specialized, functional area expertise supports their individual projects.

Resource flexibility is another major advantage of the matrix structure. Resources in the functional units (including scientists, engineers, and technicians in research and development) may be shifted between the different projects as requirements arise for their services. The resource flexibility feature of the matrix organization creates several unique opportunities for cost savings. First, fewer total resources may be required, since the same resources can be shifted between projects as needed. As a corollary of this condition, idle resources can be reduced through such project shifting.

Furthermore, due to the resource shifting, a cross-fertilization of ideas takes place between projects, thereby averting costly "reinventions of the wheel" and repetition of errors. The elimination of redundant research and resultant cost and time savings are of special importance to multi-project research and development operations.

However, off-setting these distinct advantages of matrix organization are certain associated and complex problems. Perhaps the most critical problem is the violation of the classic management principle known as unity of management (often referred to as unity of command). Since work force members in the various functional area units report not only to their functional heads but also to the authority-sharing project managers (according to the diagonal chain), it is likely that they will eventually be given conflicting orders by their various bosses.

From a similar perspective, the sharing of authority by functional and project managers can result in violation of the management principle that job authority and responsibility should be commensurate. Although functional managers have responsibility for operations within their functional areas, they share authority over their functional area resources with the project managers. The reverse is also true in that project managers are responsible for their projects, but share resource allocation and supervisory authority with functional managers. Complicating this situation further, due to the multiple chains of management, the project and functional managers may not even be aware of what directives have been issued involving resources for which they are accountable.

The above conditions can cause intense organizational conflicts which may nullify any advantages associated with the matrix structure. One approach to minimizing these matrix problems involves allowing functional area managers to retain final authority in all project-specific functional area decisions. However, this structural arrangement can restrict or preclude the project manager from freely and optimally utilizing functional area expertise and resources.

A more common way to seek to minimize matrix-related problems, but certainly not a panacea, is to concentrate on the proper selection of functional and project managers for the matrix organization. Since teamwork and cooperation are extremely important to the efficient operation of a matrix structure, only team-sensitive managers should be chosen to head major functional and project divisions. However, due to the unique combination of managerial ability and leadership personality required by the matrix structure, the task of finding such qualified managers is indeed formidable.

Table 1 summarizes some of the key strengths and weaknesses of the specialty-based, process-functional based, and matrix-project based structures.

## CONCLUSION

Although an academic presentation can differentiate organizational structures by distinct categories with associated advantages and disadvantages, the realities of institutional management often dictate a blending of features from each of them. The selection of the proper mix of structural characteristics is one of the most important decisions management can make, since organizational structure ultimately serves as the "glue" holding an institution together. The strength of this glue is especially significant to the management of business institutions in which research and development play a dominant role, since the bonding of science and engineering with manufacturing and marketing in an efficient production team is vital to the successful operation of firms in highly competitive global environments.

Will these three traditional organizational structures survive in the future? Probably so. However, there is a trend toward subcontracting functional area tasks to outside organizations (10). Since, historically, the research and development sectors of an organization are first to fall under critical examination during times of economic stress, organizations of the future may increasingly entrust their research and development needs to subcontractors. If this ~~is~~ scenario materializes, the integration of research and development with other critical organizational functions and processes may become even more difficult to achieve and sustain. However, paralleling this trend toward subcontracting is a concurrent realization that research and development are the cornerstones of global competitiveness. As such, it seems safe to conclude that the integration of research and development with manufacturing, marketing, and other critical organizational activities will remain a primary managerial concern.

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Table 1

## SOME STRENGTHS AND WEAKNESSES OF SPECIALTY, PROCESS-FUNCTIONAL, AND MATRIX-PROJECT STRUCTURES

### Specialty-Based Structures

* Strengths:
- Encourages supportive work environment.
- Shelters the specialty-based unit from potentially distracting extraneous influences.
- Encourages managerial efficiency through allowing more homogeneous work to be supervised.

* Weaknesses:
- Limits direct integration of specialists with others whose own work effectiveness depends upon the specialists.
- Can lead to a myopic perspective where the pursuit of specialty excellence is of paramount importance.
- Limits cross-fertilization of ideas across specialties.

### Process-Functional Based Structures

* Strengths:
- Interdependency of units can promote institutional teamwork.
- Interdependency of units can reduce political infighting between professional specialists.
- Encourages employee appreciation and understanding of his/her unit's contribution to the total production effort.

* Weaknesses:
- Specialty identification loss may lower morale.
- Discourages the development of general managers with cross-functional experience.
- Interdependency of units can exacerbate the negative impact of weak units.

Table 1
(contd.)

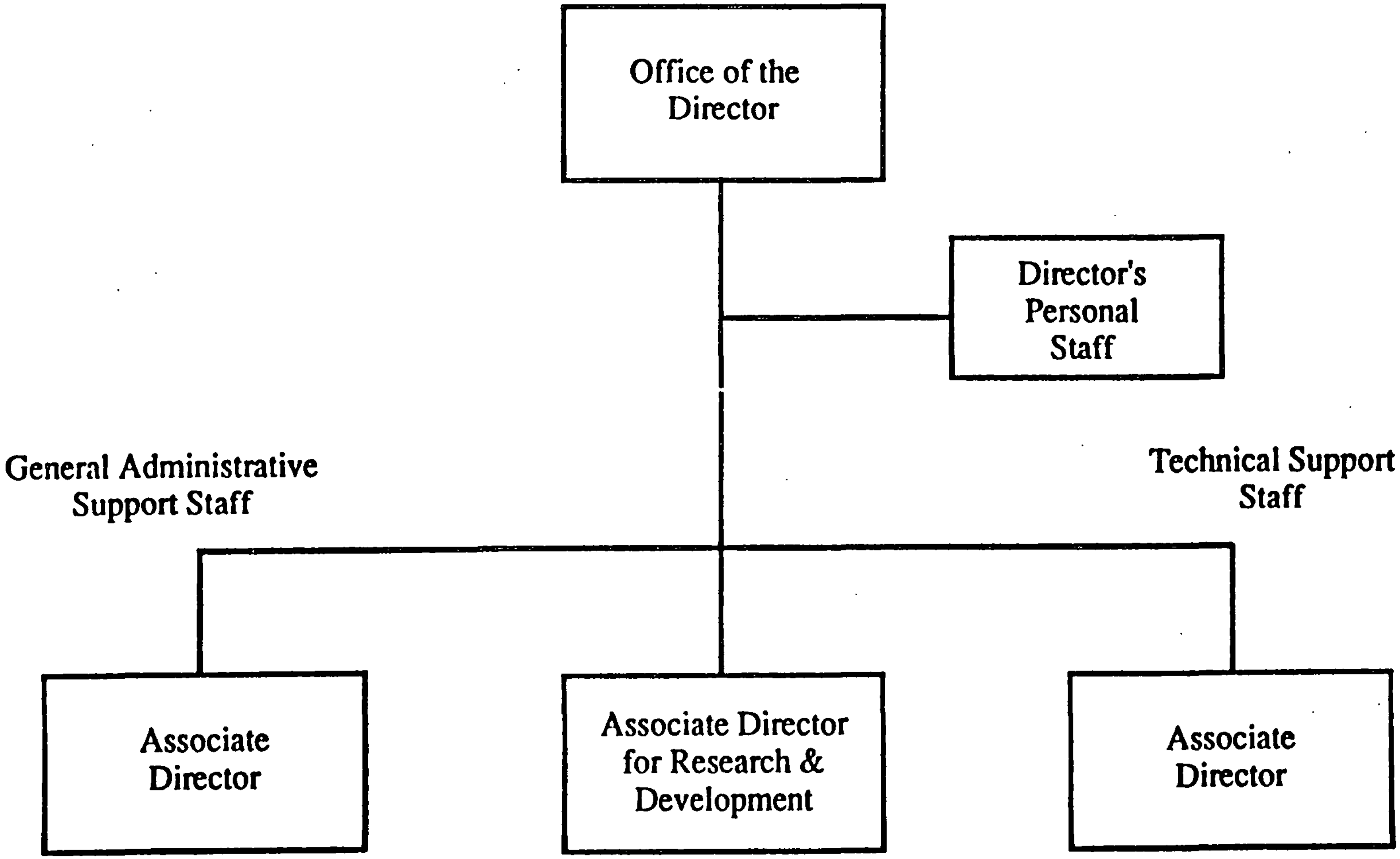
## Matrix-Project Based Structures

* Strengths:
- Accommodates multiple, concurrent, and diverse projects.
- Enables project managers to monitor and, to an extent, direct all functional area activity relating to their projects.
- Minimizes the required resource base by facilitating the shifting of resources between projects.

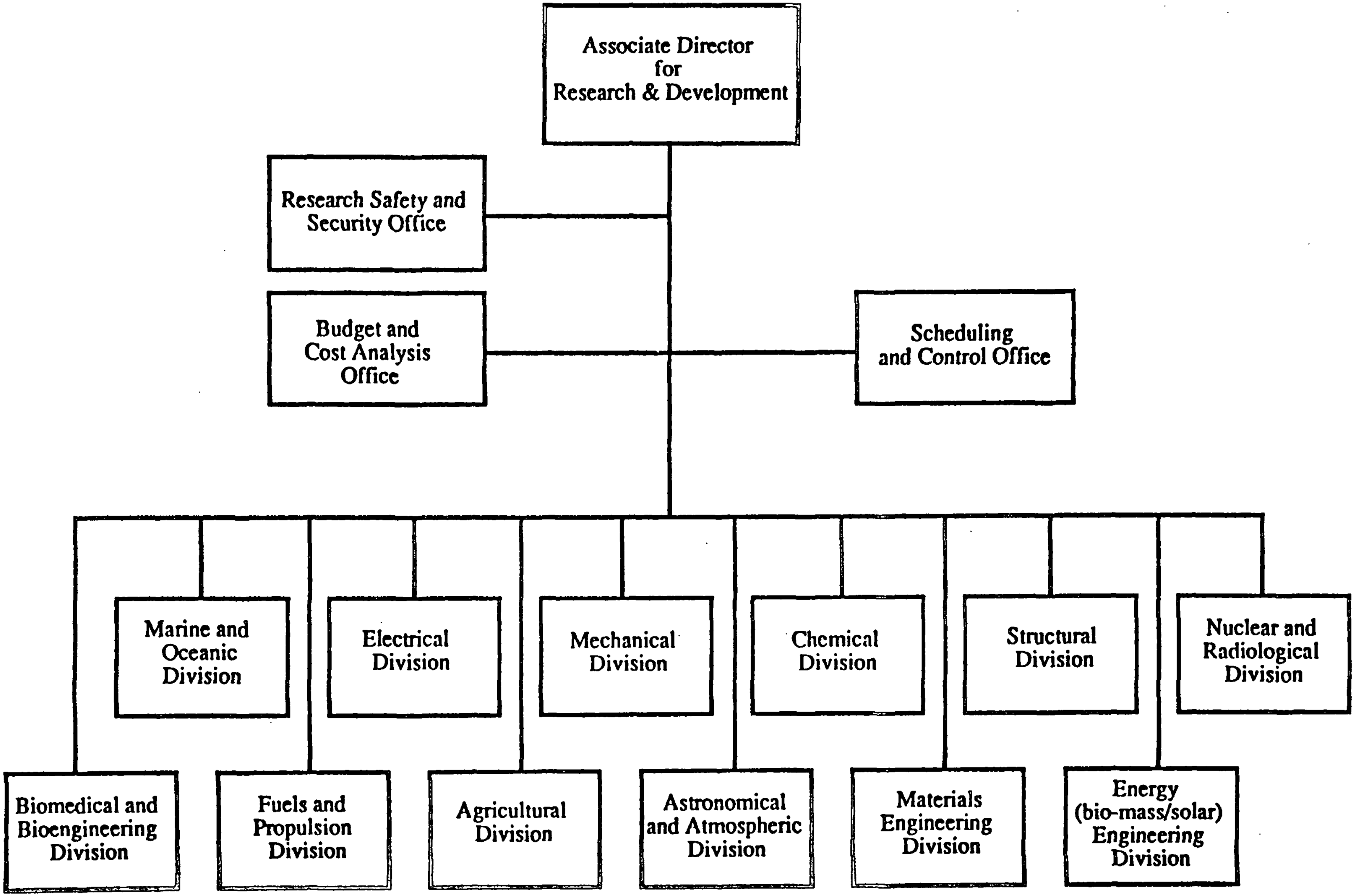
* Weaknesses:
- Violates the unity of management/command principle.
- Managers may be held accountable for noncontrollable resources and results.
- High potential for matrix managers to be ignorant of decisions made by their project or functional area counterparts.

CHART A

# A SPECIALTY BASED RESEARCH & DEVELOPMENT ORGANIZATION



# CHART A1


Associate Director for Research & Development
Research Safety and Security Office
Budget and Cost Analysis Office
Scheduling and Control Office
Marine and Oceanic Division
Electrical Division
Mechanical Division
Chemical Division
Structural Division
Nuclear and Radiological Division
Biomedical and Bioengineering Division
Fuels and Propulsion Division
Agricultural Division
Astronomical and Atmospheric Division
Materials Engineering Division
Energy (bio-mass/solar) Engineering Division

## CHART A2

### Technical Support Staff

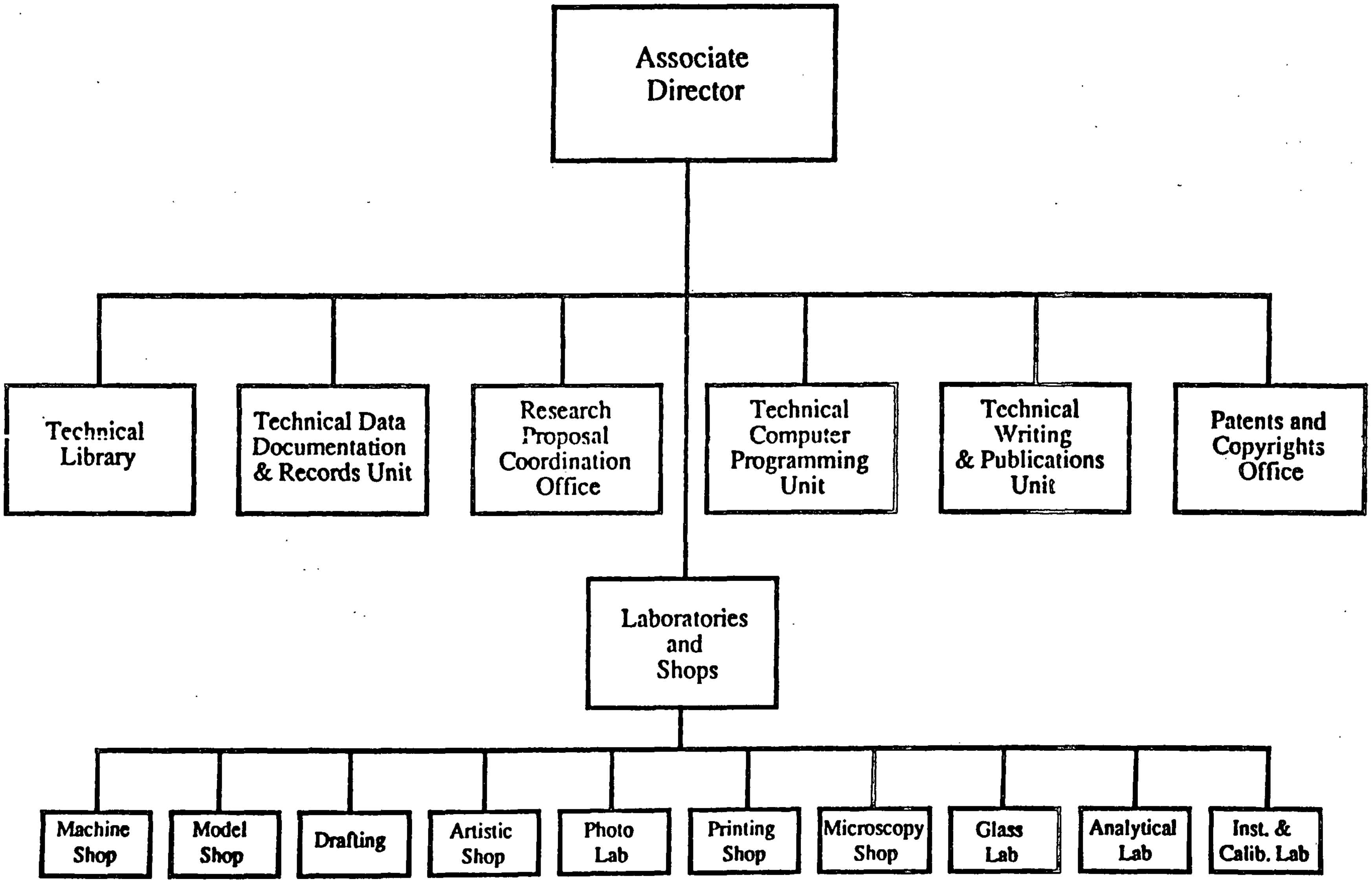


CHART A3

General Administrative
Support Staff

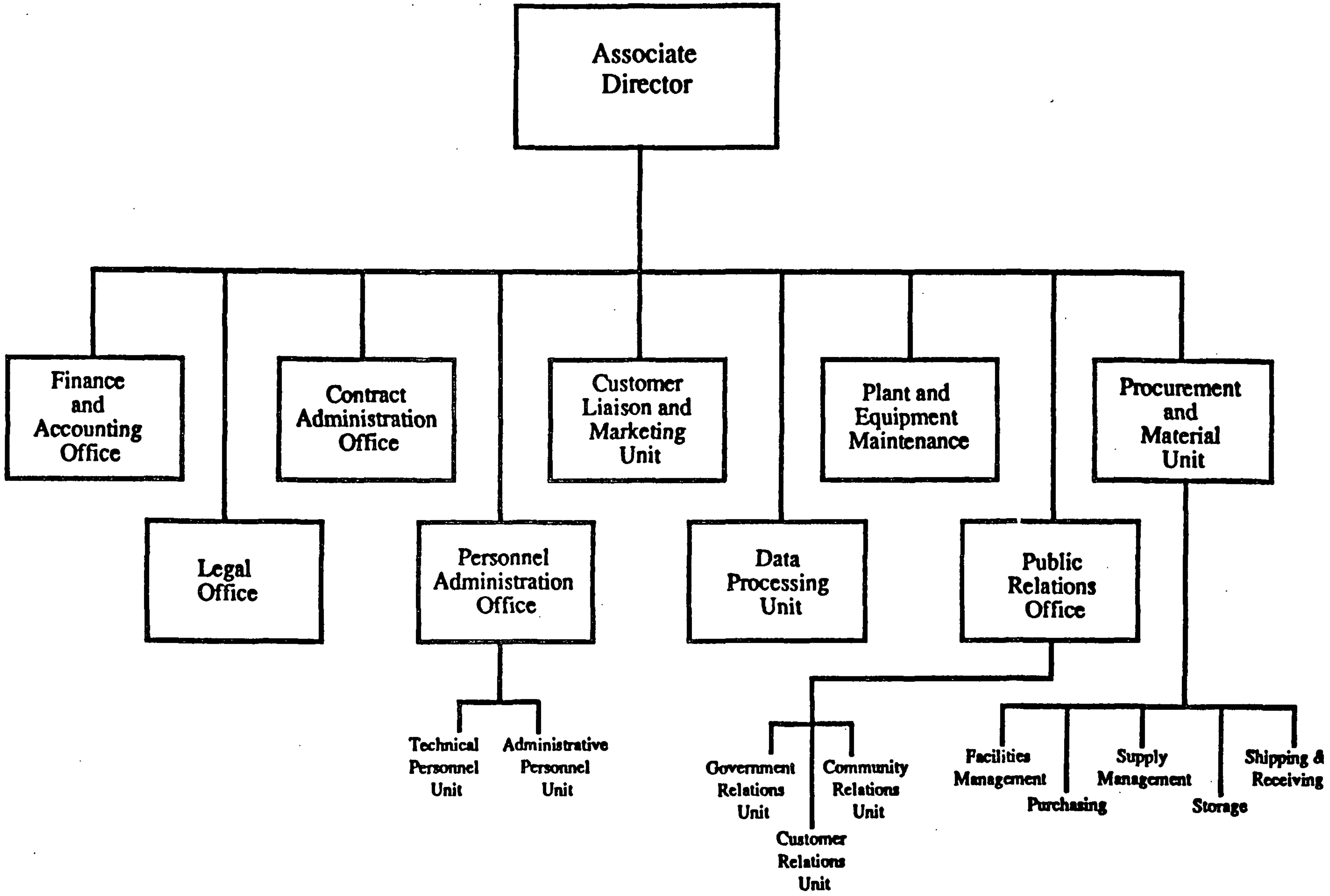


CHART B

# AN INTEGRATIVE PROCESS-FUNCTIONALLY BASED MANUFACTURING FIRM ORGANIZATIONAL MODEL (LINE UNITS)

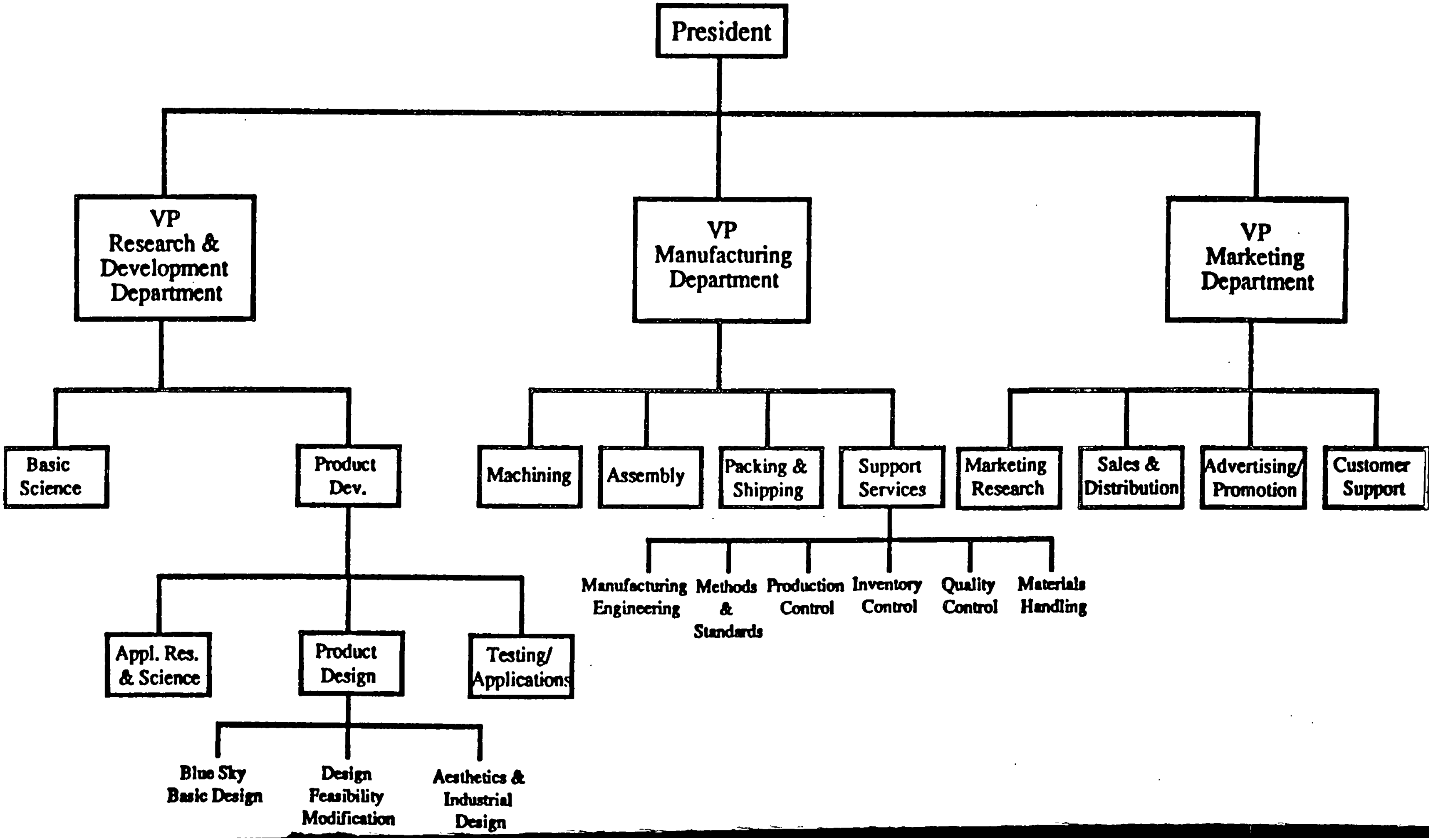


CHART B1

# AN INTEGRATIVE PROCESS-FUNCTIONALLY BASED MANUFACTURING FIRM ORGANIZATIONAL MODEL (STAFF SUPPORT UNITS)

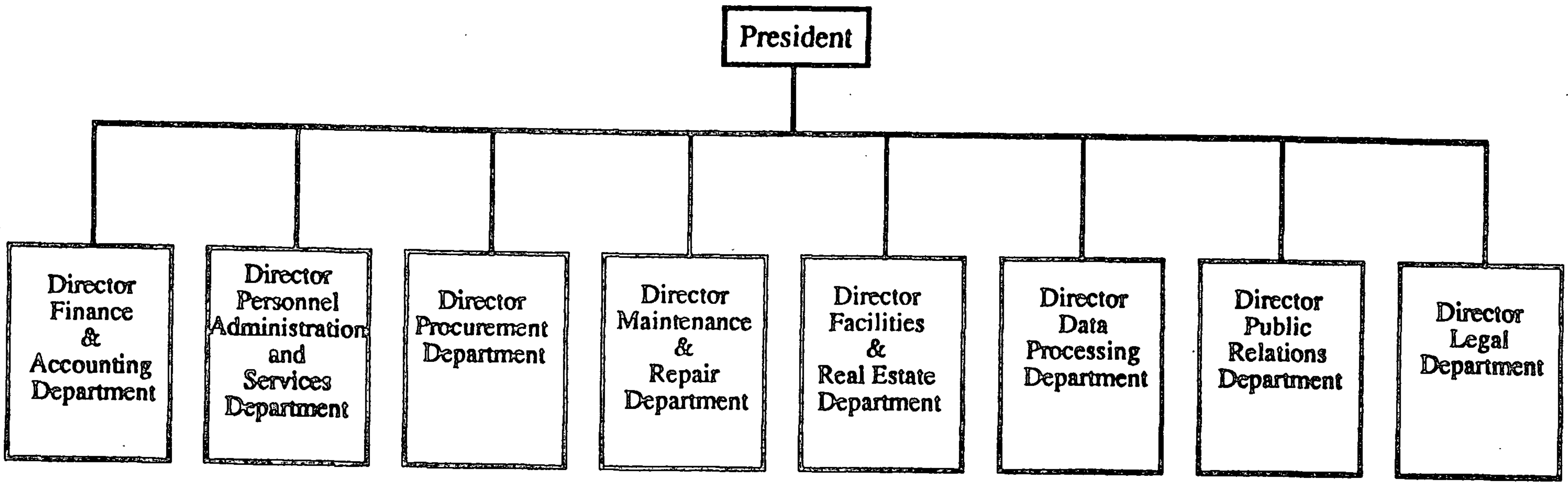


CHART C

# A PROCESS-FUNCTIONALLY BASED RESEARCH & DEVELOPMENT ORGANIZATION

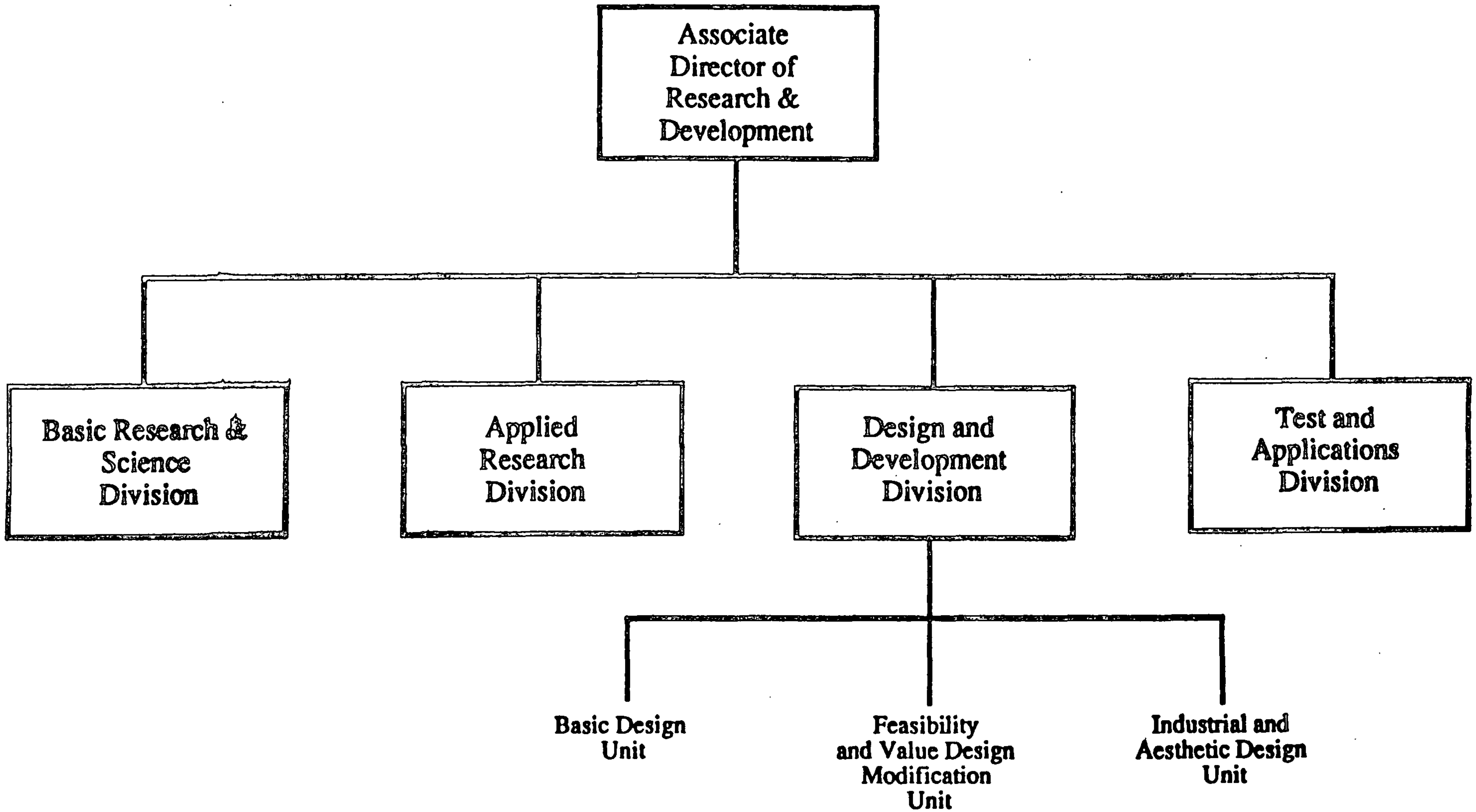


CHART D

# A PROJECT-PRODUCT ORIENTED RESEARCH & DEVELOPMENT ORGANIZATION